CHARACTERIZATION OF FULL SIZE MWT BACK CONTACT AND H-PATTERN MODULES BY OUTDOOR IV-TRACING MEASUREMENTS AND EXPLANATION OF THE DIFFERENCE IN ENERGY YIELD

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ABSTRACT: ECN has developed modules with Metal Wrap Through (MWT) cells glued on a electrical conductive Back Contact (BC) foil. The properties of the MWT-BC modules and a standard H-pattern module were investigated by outdoor IV tracing measurements. For both modules, the short circuit current is linear with the irradiance. The power output of the MWT-BC module is also linear with the irradiance, while the H-pattern module deviates from linearity at increasing irradiance. The deviation from linearity is explained by the higher series resistance of the H-pattern module due to the ohmic resistance of the busbars. The gain in yield due to the lower resistance of the MWT-BC module is calculated from the power output of the out-door IV tracing measurements at ECN (Amsterdam area, The Netherlands). The gain in yield will be even higher for southern countries and future modules having higher efficiency and improved light incoupling.

Keywords: Energy Performance, MWT, Back Contact, Outdoor, IV tracing

1 INTRODUCTION

The current industrial standard for wafer based x-Si modules is the H-pattern module. For the production of these modules, strings of H-pattern cells have to be made. The manufacturing of these strings is time consuming, requires a lot of handling, often results in (micro)cracks and power loss of cells or even complete strings.

An alternative for the H-pattern module is the Back Contact module with Metal Wrap Through cells, the so-called MWT-BC module. At ECN we have developed this type of module [1] by using conductive adhesives for the electrical interconnection of the back of the cells with the electric conductive back sheet foil (Figure 1). These modules have many advantages compared with standard H-pattern modules, such as lower shadow losses by omitting the frontside busbars, low internal stress, reduced production time and handling cost, smaller area between the cells and a low series resistance. Due to the low series resistance, the electrical losses are lower compared to standard H-pattern modules with busbars, especially at high irradiance.

For the determination of the advantages of MWT-BC modules under real operating conditions, a MWT and a H-pattern module were characterized in detail at ECN for almost 2 years by outdoor IV tracing, including irradiance and temperature measurements. The data of the measurements were used for the determination of the increase in yield of the MWT-BC module by the lower series resistance.

2 EXPERIMENTAL

2.1 The modules

The MWT-BC module consists of 60 MWT cells with a diameter of 6” per cell. The cells are electrically connected to the conducting back sheet foil by conductive adhesive, which is cured simultaneously with the curing process of the EVA in a laminator at 150°C. This low temperature one-step process reduces the production time of the modules while also keeping internal stresses on the cells low. More information on the MWT-BC module can be found in [2].

The H-pattern module is a commercial available German module, consisting of 54 cells with 2 busbars of 2.5 mm width per cell and a cell diameter of 6”.

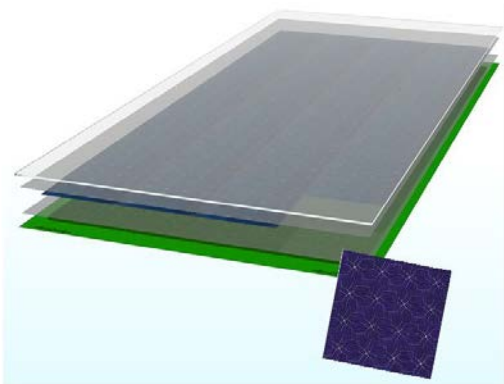

Figure 1. Built-up of MWT module. From bottom to top: conductive back sheet foil, EVA, MWT-BC cells, EVA and front glass.

2.2 The IV tracing outdoor test facility

The modules were tested at the out-door test facility of ECN for almost 2 years at a tilt of 30° and azimuth of 174° (Figure 2). In this facility, every 10 minutes an IV curve is measured at a measuring time of 1 second. From the IV curves the values for Isc, Voc and Pmpp were extracted. In between the measurements, the modules are kept in the maximum power point.

The irradiance was measured by a x-Si reference cell, placed in plane with the modules. The temperature of the modules was determined by a PT100 thermocouple as fixed at the back in the middle of each module. From this temperature, the temperature corrected values for the Isc, Voc and Pmpp at 25°C were calculated by assuming temperature coefficients of 0.03%, -0.335% and -0.45%/K for the current, voltage and power output, respectively.

The pyranometers, KG3 filtered reference cell and ambient temperature sensor were not used in this study. Details of the facility, as available for external parties, can be found in [3]. Currently, the facility is extended and has a capacity for IV tracing of 22 modules.

Figure 2: Part of IV tracing system at ECN with 60 cell MWT module (left) and 54 cell H-pattern module (right).

3 RESULTS

3.1 Short circuit current as function of the irradiance

In Figure 3 the temperature corrected short circuit current (I_{sc25}) is given as function of the irradiance. This figure clearly shows that the current is directly proportional with the irradiance and equal for both modules. For STC conditions, the Isc is 8.23A as comparable with the indoor flash measurement of the back contact module.

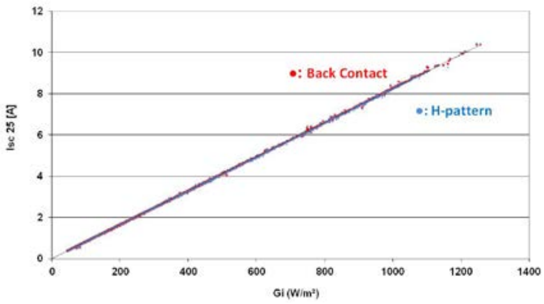

Figure 3. Temperature corrected short circuit current as function of the irradiance for the MWT-BC and H-pattern module (data of June 2011)

3.2 Voltage in time at given irradiance.

In Figure 4, the Voc of the MWT-BC module is given in time at an irradiance of 500 W/m² in a bin of ±5W/m². The voltage is given as measured (V_{oc}) as well as the temperature corrected values (V_{oc25}). The measured voltage clearly deviates during the day, while the temperature corrected value is constant. This figure clearly shows that the temperature measured at the back of the module is representative for the temperature of the cells. This also holds for the H-pattern module (not shown).

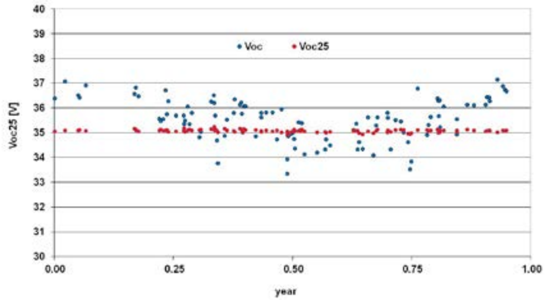

Figure 4. Measured and temperature corrected open cell voltage in time at an irradiance of 500±5 W/m² (2011)

3.3 Power output as function of the irradiance

In Figure 5 the temperature corrected power output (P_{mpp25}) is given as function of the irradiance. Since the number of cells in the modules is different, the power output is given per cell. The power output of the back contact module is nearly linear with the irradiance, showing the low series resistance of the back contact module. The power output at STC condition is 227 Wp, as comparable with the indoor flash measurement.

For the H-pattern module the power output deviates from linearity at higher irradiance due to the series losses being higher for H-pattern modules compared with back contact modules. At an irradiance of 1000 W/m², the power output of the H-pattern module is about 140 mW/cell lower than the MWT-BC module.

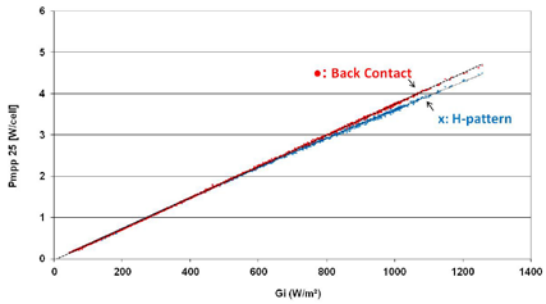

Figure 5. Temperature corrected maximum power output per cell as function of the irradiance of the back contact and H-pattern module (data of June 2011)

The electrical loss of the MWT-BC module by the conductive foil and conductive adhesive was calculated by FEM analysis [4]. For the H-pattern module, the electrical losses of the busbars were calculated by the estimation of the effective resistance of the busbars. From these calculations the difference in loss of the H-pattern and MWT-BC was estimated to be 126 mW/cell, comparable with the measured difference in power of 140 mW/cell.

In Figure 6 the temperature corrected efficiency is given as function of the irradiance. For a fair comparison, the calculated efficiency is based on the aperture area of the modules. Due to the low series resistance of the back contact module, the efficiency is nearly constant for higher irradiance. For the H-pattern module the efficiency decreases at higher irradiance.

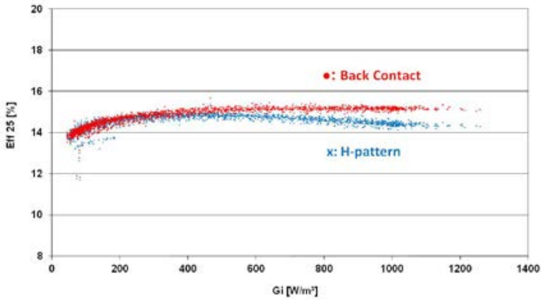

Figure 6. Temperature corrected efficiency (aperture area) as function of the irradiance of the back contact and H-pattern module (data of June 2011).

Due to the higher efficiency, the MWT-BC module will have a higher yield at higher irradiance compared with the H-pattern module.

3.4 Difference in yield of MWT back contact and H-pattern modules at ECN (Petten, the Netherlands).

The difference in yield of the modules depends on the irradiation distribution. Often the irradiation distribution is calculated from hourly or even daily average values. For stochastic hourly averages, the maximum irradiation in West European countries is around 600 W/m² irradiance, while hardly no irradiation can be found above 1000W/m² [5].

For accurate irradiation distribution, irradiance data on second scale in needed [5,6]. In Figure 7, the irradiation distribution is given for 2011 in Petten, as measured with the IV tracing outdoor test facility at ECN. The irradiation distribution is based on the irradiance measurements of average values per second, being representative for the sampling time of mpp trackers of inverters. The figure clearly shows that the maximum irradiation can be found for a irradiance level around 900-950 W/m², while values higher than 1000 W/m² are measured for the periods having direct sunlight with additional energy from scattering clouds.

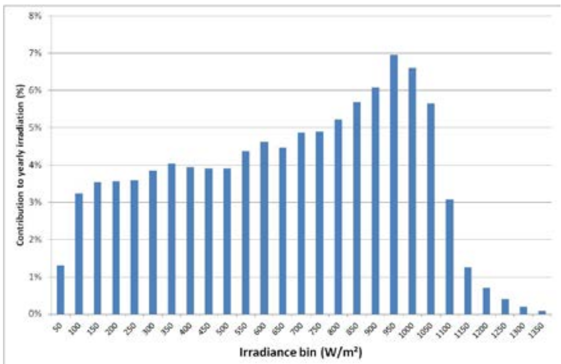

Figure 7. Measured irradiation distribution for Petten (the Netherlands), based on second averages (tilt: 30°C, bin 0-50, 50-100, ….)

In Figure 8 the power output per cell is given of the MWT-BC module divided by the power output of the H-pattern module as function of the irradiance. Since the IV curves of the modules and the irradiance are measured at exactly the same time, this direct comparison can be made.

At low irradiance, the performance of this particular MWT module was about 1% lower compared with the H-pattern module, which could be subscribed to for instance differences in cells, encapsulant and glass. At increasing irradiance, Figure 8 clearly shows that the relative power output of the MWT-BC module increases with about 5% as function of the irradiance, showing the benefits of the low series resistance of this type of module.

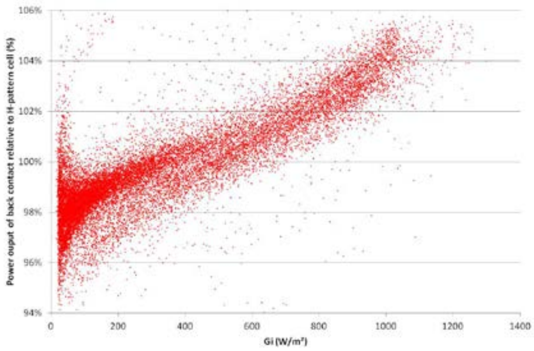

Figure 8. Power output of the MWT-BC module relative to the H-pattern module as function of the irradiance.

From the power output of the modules, it is calculated that the yearly yield of the given MWT-BC module is about 2% higher compared with the measured H-pattern module in Petten, the Netherlands. This could be even higher in case the same type of cells, encapsulant and glass was used for both modules, considering the about 1% lower power output at low irradiation for this particular MWT-BC module.

By future improvement of the cells and light incoupling of the modules, it is expected that the current of the modules will increase. For these modules the benefit of MWT-BC technology compared with H-pattern technology will be even higher. Also for more southern located countries, having a higher contribution of higher irradiance levels to the total irradiation, the advantage of the MWT-BC technology will be higher.

4 CONCLUSIONS

MWT-BC modules have a lower series resistance compared with H-pattern modules. Due to the lower series resistance, the power loss by ohmic losses of MWT-BC modules is lower, especially at high irradiance.

For the comparison of the MWT-BC technology with the H-pattern technology, the modules were characterized by outdoor IV-tracing measurements at ECN in Petten, the Netherlands. For both modules, the short circuit current was directly proportional with the current. The temperature corrected power output of the MWT-BC module as function of the irradiance was also proportional with the irradiance, where the H-pattern module deviates from linearity at increasing irradiance by the higher series resistance. The estimated electrical loss by the series resistance for the H-pattern module at an irradiance of 1000W/m² is comparable with the calculated electrical loss of the busbars of the H-pattern module.

The power output of the MWT-BC module relative to the H-pattern module increases by about 5% as function of the irradiance. The measured yield over the year in Petten (the Netherlands, 2011) of the MWT-BC module was about 2% higher compared with the H-pattern module. This would be even higher in case the power output at low irradiance of this particular MWT-BC module was not 1% lower compared with the H-pattern module which could be caused by for instance differences in cells, encapulant and glass of the modules measured.

The increased higher yield for the MWT-BC module will be even higher for southern locations and future modules with more efficient cells and improved light incoupling by the higher current levels.

8 REFERENCES

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